# BCI Lecd-1

⇒ AI

⇒ Units

→ Intro to BCI ✓

→ Intro to NeuroSceince.

→ Modeling & Recording Brain Signals

→ Signal processing

→ Signal Analysis using ML

→ BCI Applicatin

⇒ Application

⇒ Medical

→ Sleep disorder

→ Paralysed body control

⇒ Challenges

→ Usability

→ hardware

→ Signal processing

→ System integration

→ Cost

# Intro to Neuroscience

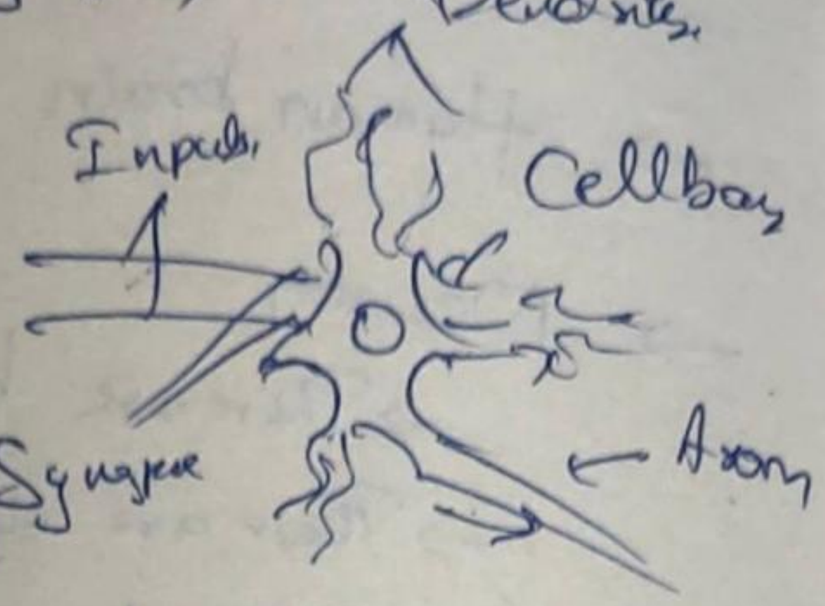
→ Human brain structure

→ Neuron
  → There are billions of neuron in our brain.
  → These are main cause for signals by current.

→ Inside neuron there is a charge. (ions)
→ impermeable membrane allows only some ions not all.
→ ions : $[Na^+]$, $[Cl^-]$, $[Ca^{2+}]$, $[k^+]$, $[A^-]$
→ Neuron maintains potential diff
  ±70mV to ±80mV
→ $[Na^+]$ $[Cl^-]$ & $[Ca^{2+}]$ higher outside
  $[k^+]$ $[A^-]$ higher inside.

→ Ionic pump maintain -70mV differen by expelling. $Na^+$ Out & allowing $k^+$ ions in
→ During transfer of memory this occurs
→ Voltage-gated: Diff in voltage
  Chemically-gated: Upon receiving a chemical.
  Mechanically-gated - pressure or stretch
  These 3 are cause for transfer.

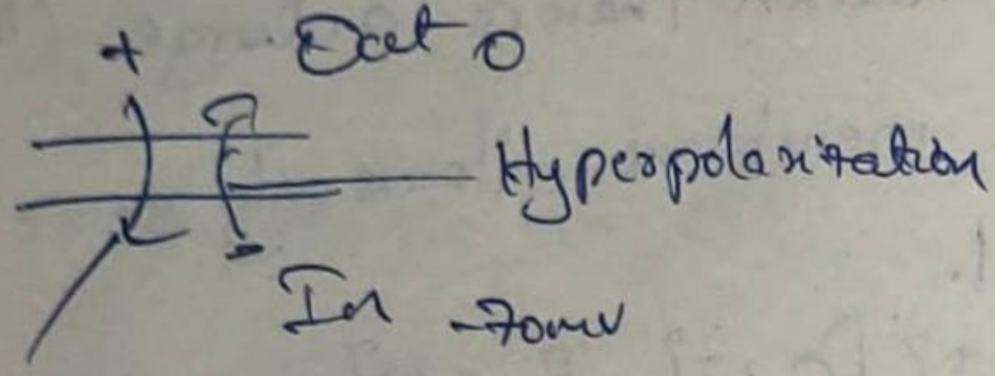
→ Chemically-Gated (at synapses) → other neurons

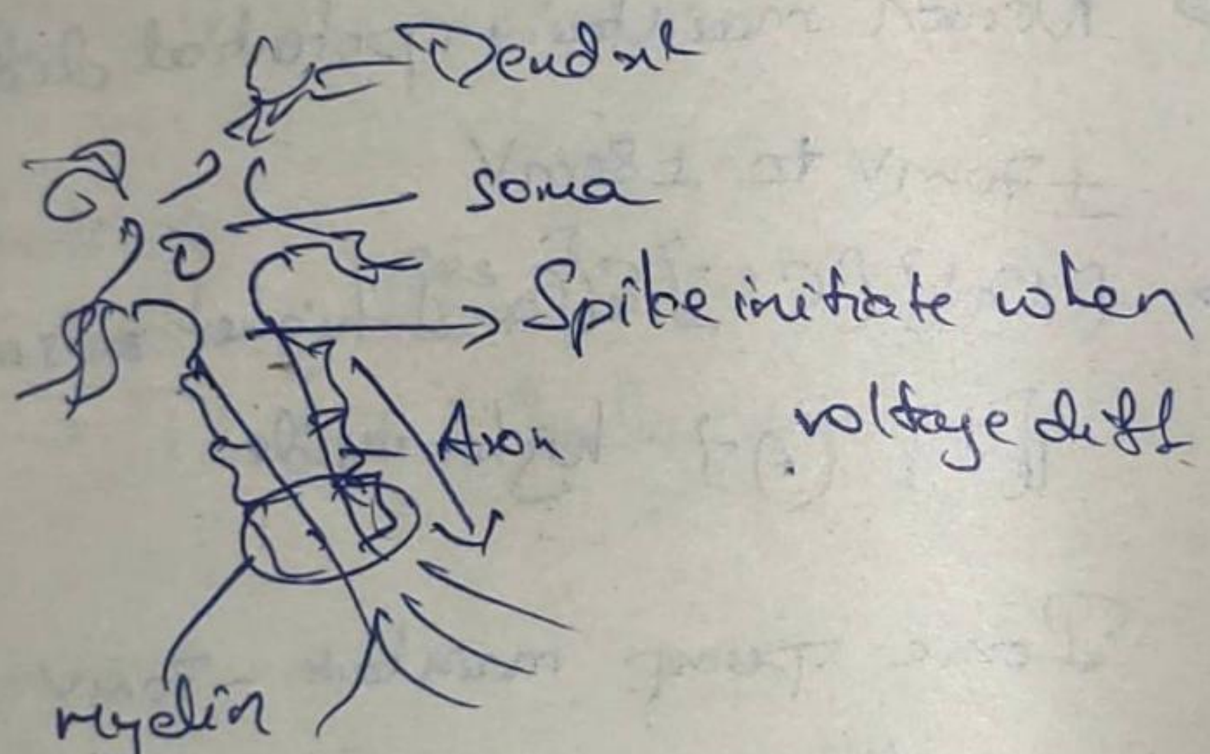



→ This cause voltage diff.

depolarization (positive charge)

hyperpolarization (negative charge)




→ Synapses Can be electrical but mostly chemical

→ Presynaptic neuron → post synaptic neuron

→ Chemical → neurotransmitters.

→ Synapses Excitatory or inhibitory

Incr ↑ PSP Post Poten firing a spike by postsynaptic

↓ IPSP decrease

* Explain long Term & Short Term again

→ Na+ influ

Order :

I/P spike → Neurotransmitt → Bind to Na

→ Na+ influx → Depolarn (EPSP)

I/P spk → Neurotran → Bind with k+ channel

→ k+ leaves cell → Hyperpolar (IPSP)

→ Rapid influx of $Na^+$ & opening of $k^+$ ions creates is called spike Communicate b/w one neuron to other neuron.

→ When ions transfer a spike is emitted

→ LTP (Long Term Potentiation) . firing b/w neurons for hours & more. (Cerebellum, hippocampus, neocortex)
LTD (long Term Depression)

→ STDP (Spike timing dependent plasticity)

→ Short-Term Facilitation/depression

Immediate changes

Neuron - synapse - strength & Connection.

Central Nervous System (CNS) Brain, Spinal

Peripheral Nervous System (PNS) Skeletal muscle, Autonomic
or Heart
Skeletal Respiration

| | PNS | CNS |
|---|---|---|
| Afferent | body to brain | |
| | CNS | PNS |
| Efferent | brain to body. | |

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Brainstem - Midbrain (Eye movement, visual, audition reflex)
Cerebellum (Voluntary movement & sense of equilibrium)
Pons (Sleep & arousal)
Medulla. (Breathing, BP, muscle tone)

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Thalamus :- All sensory except smell

Hypothalamus :- fighting, fleeing, feeding, mating.

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Cerebral Hemisphere: -

Cerebral Cortex, basal ganglia, hippocampus, amygdala

Perception & motor control, emotion etc

2yr

Invasive (Surgery) Eg. - Implanted Electrodes (Wire)
fine wire (Tungsten or platinum

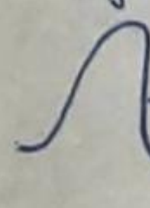
Non-Invasive (No Surgery) Eg: EEG

Invasive

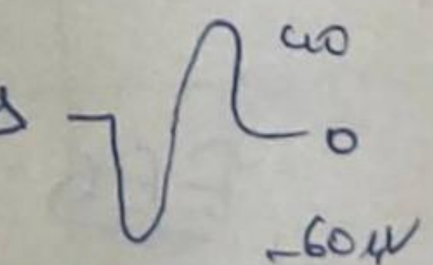
→ Microelectrode into brain record upto neuron level.

→ Intracellular Recording (patch clamp recording)

Voltage diff of a neuron.




→ Extracellular Between two neurons




Initially positive ions flow away during spil
Cause ~~positive~~ neg deflection.

→ Tetrods & Multi-unit Reco :

4 wires

→ Multielectrode Array

have many wires like #

→ Ability to Record from many neurons at a time.

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Partially Invasive

Electrocorticography (ECoG):

→ Place electrode on surface of brain sh
→ 1 cm apart

Micro ECoG

→ Same but 2 → Mmar

→ Finger movement, --

Optical Recording Voltage-Sensatie Dye & Two-photon
Calcium Imaging.

→ Check sum pot diff

→ Check imaging

Two photon calcium.

Check the calcium concentration.

→ pressure ejection wa

EEG

→ Neuron transmit both electrical & Chemical signals.

→ Sensory input → integration & motor output

* Hyperpolarisation :- Outgoing of $k^+$ ions

* Depolarization :- Income of $Na^+$ ion

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## Post synapthic potential

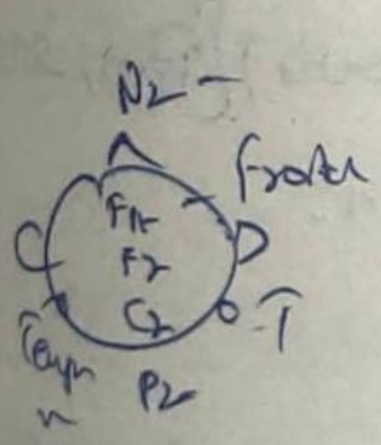
~~Extreme~~

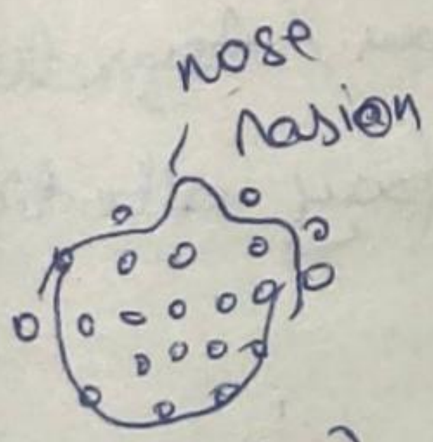
Excitory :- Depolarisation goes very high

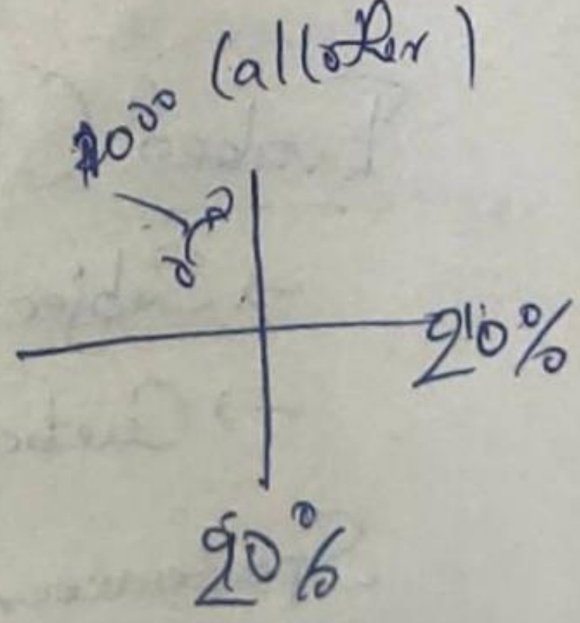
Inhibitory - Hyperpolarisation goes too low.

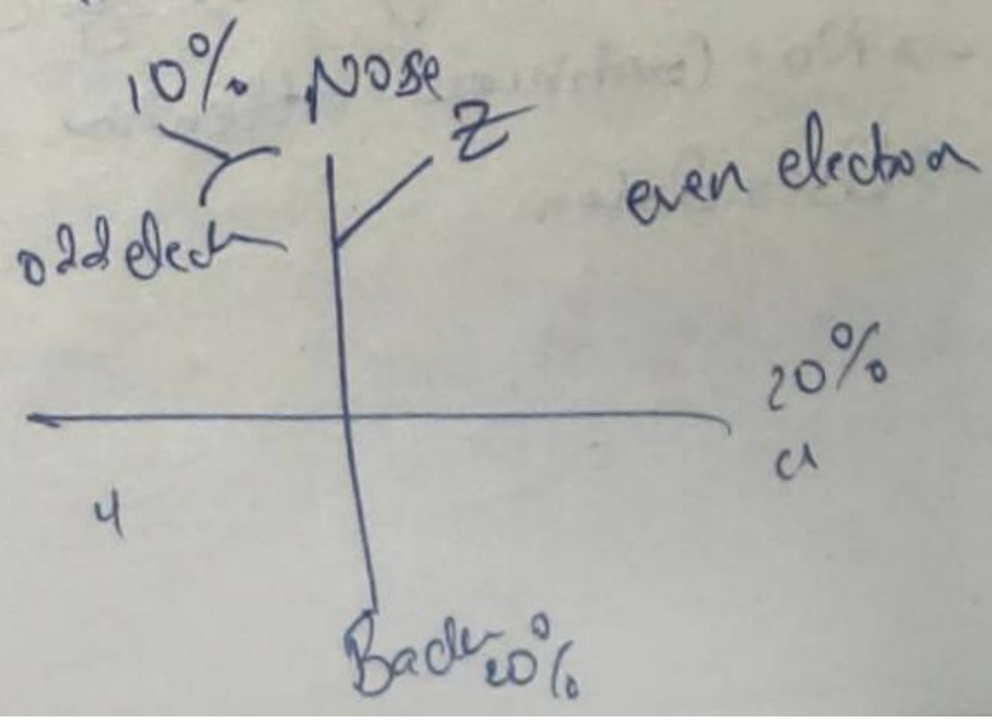
In EEG we record neuronal activity electric signals.

## Electrode placing



## Measuring EEG

Ground - diff b/w the participant & the amplifier

→ A-Gr, R-Gr
→ Measured with respect to Reference part

→ EEG channels is refered to as montage.

→ Unipolar/Referential = diff b/w electrode & reference.
→ Bipolar: Diff b/w adjacent (ECG, EOG)
→ Potential diff are amplified & filtered.

Q:- When will potential will go too high?

## Event-related potential,

Evoked (Endogenous / Asynchronous) {P300, SSEP/SSEP VEP}

→ Subject must pay attention.
→ Cue based

Spontaneous. (Exogenous / Synchronous) } (FFR, SCP) Medical

→ No. Continuous attention.
→ User Driven

ERP

→ Averaging of trails follow a stimulus

ERP is Purely attention how can it be spontaneous

→ Doing many trails and making avg.

→ Deflections can be +'ve & -'ve

Positive after 100ms → $P_{100}$

Negative after 100ms → $N_{100}$

VEP (Visual Evoked Potential) Low Freq flash.

$P_z$ & $O_z$

↓ vision.

processing info

Steady - State Visual Evoked Potential (SSVEP)

3.5 Hz to 75 Hz Higher Freq range.

$P_{300}$ ← ERP

→ Positive Curve on EEG after 300ms

→ 95% of accuracy

Concentrate based on signal it will identify.

# ERS/ERD (Event Related De/Synchronization)

Change in signal power relative to reference

ERS → Increase in power.

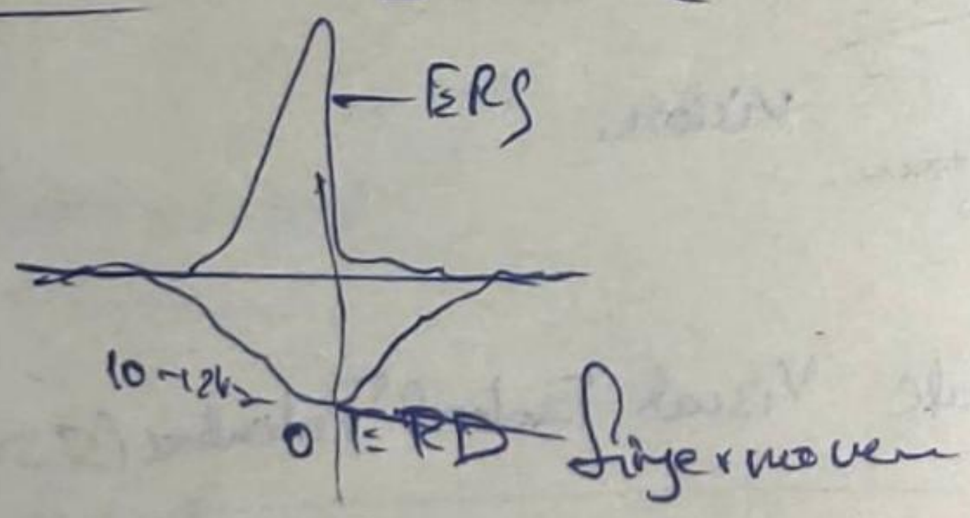
Associated with activity dec

ERD → Decrease in power.

Associated with activity incre

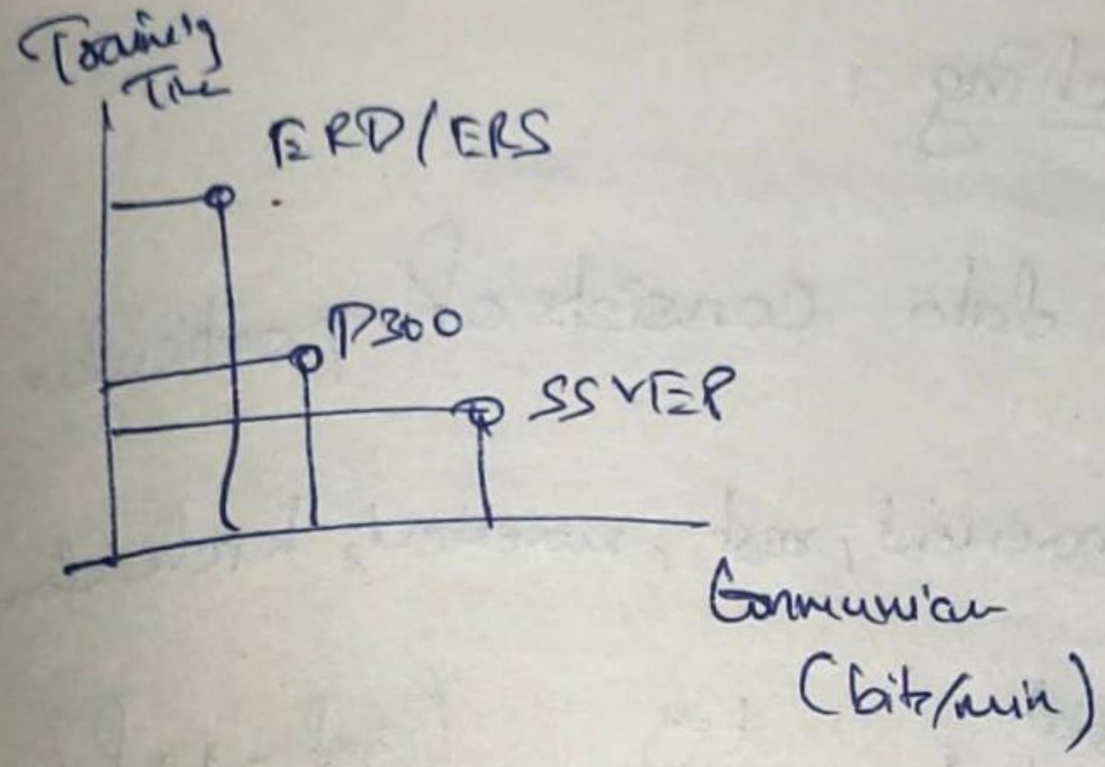
When a person think to move hand initially become weaker & then stronger.

Hand movement → Cz electrode (Motor movement)




Q: Does at each stimulus both ERS & ERD occur?

Delta – 0.5–4 Hz
Theta – 4–7 Hz
Alpha – 8–13 Hz (μ)
Beta – 14–18 Hz
Gama – 36–40 Hz & and 50 Hz

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Q. How do we get 25 columns in eg. dataset?

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EEG Signal Preprocessing

Q. "Cue" - meaning

Cortical activity for Imaginary vs real.

How do we set the frequency?

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Data Epoching-

Data pre-processing

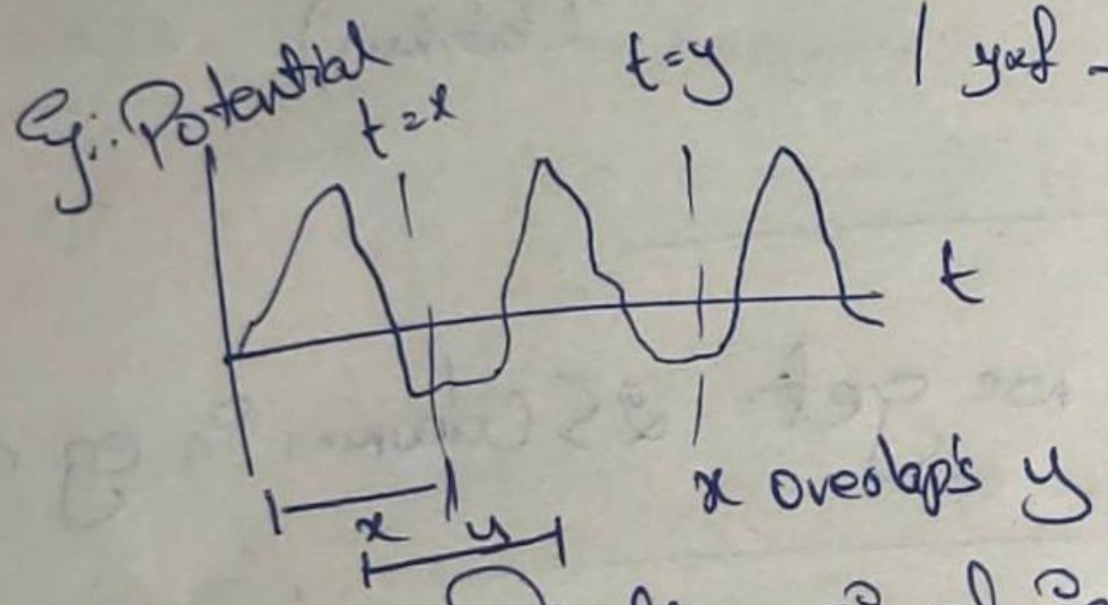
Removing data that is not required.

Data epoching :-

Our data consists of particular samples.

like rest, movement, rest, movement, kick etc

Eg: Potential




Sampling :- Dividing signal into parts of equal interval.

freq = no. of samples/sec

we take only required samples called epoching

Epoch also mean iteration.

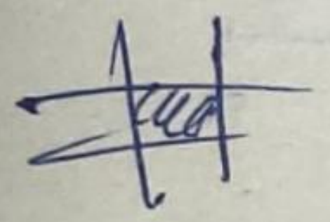
Perform training over a person called EEG

Now epoch break into parts & now get them create a ML algo to test.

Cognitive work load :- (CWL)

This is used to check the memory work and to get mental resource during a task

Eg:- n-Back Task



Give diffre alphabet with diff sound if it repeats user should identify that. then press key.

Signal processing -

SS

Any signal can be converted into sin & Cos using orthogonal basis.

Q. Brain part & its action?

Fourier series :- (Fourier Transform)

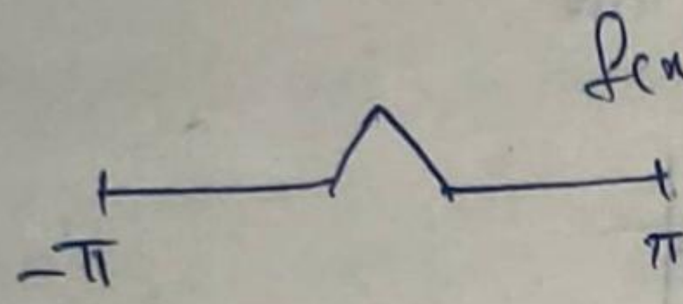
We try to replicate same signal using Increasing frequency.

$$f(x) = \frac{A_0}{2} + \sum_{k=1}^{\infty} \left[ A_k \cos(kx) + B_k \sin(kx) \right]$$

## Periodic

Reapeat at each interval.

Eg :-




Pe Period = 2π

$$f(x) = \frac{A_0}{2} + \sum_{k=1}^{\infty} \left[ A_k \cos(kx) + B_k \sin(kx) \right]$$

$A_k$ & $B_k$ are fourier constant.

$$A_k = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \cos(kx)\, dx \quad \text{(Pn way of Cos)}$$

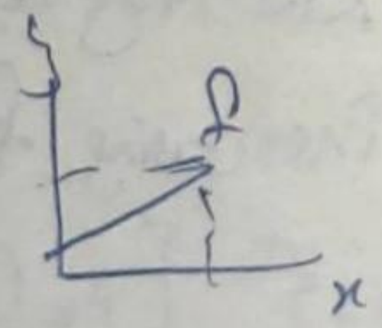
$$B_k = \frac{1}{\pi} \int_{-\pi}^{\pi} f(x) \sin(kx)\, dx \quad \text{(Pn way of Sine)}$$

$$A_k = \frac{1}{\|\cos(kx)\|^2} \langle f(x), \cos(kx) \rangle \quad \text{(like dot product)}$$

Pon

$$B_k = \frac{1}{\|\sin(kx)\|^2} \langle f(x) \cdot \sin(kx) \rangle$$

→ like giving a vector based on axis.




$\vec{f}$, $\langle \vec{f} \cdot \vec{v} \rangle \frac{\vec{v}}{|v|^2}$ + $\langle \vec{f}, \vec{w} \rangle \frac{\vec{w}}{|w|^2}$

If period is $2$.

$$f(x) = \frac{A_0}{2} + \sum_{k=1}^{\infty} A_k \cos\left(\frac{2\pi k x}{2}\right) + B_k \sin\left(\frac{2\pi k x}{2}\right)$$

$$A_k = \frac{2}{2} \int_0^2 f(x) \cdot \cos\left(\frac{2\pi k x}{2}\right) dx$$

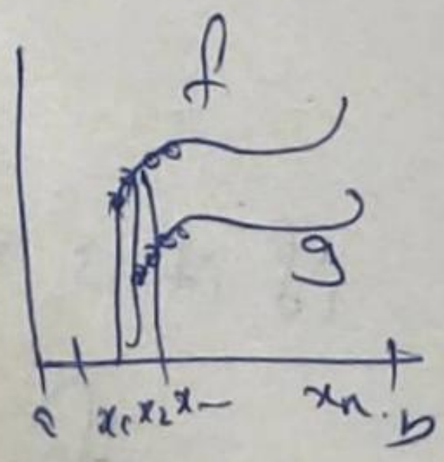
$$B_x = \frac{2}{2} \int_0^2 f(x) \cdot \sin\left(\frac{2\pi k x}{2}\right) dx$$

## Inner product of functions

Discretising to n points.

$$f = [f_1 f_2 \cdots f_n]^T$$

$$g = [g_1 g_2 \cdots g_n]^T$$




$$\langle f(x), g(x) \rangle = \int_a^b f(x)\, g(x)\, dx$$

$$\frac{b-a}{n-1} \langle f, g \rangle = \sum_{i=}^{n} f(x_k) \cdot g(x_k) \cdot \Delta x$$

of Raymon approximation

$\sqrt{n \to \infty \quad \Delta x \to 0}$

# Fourier Series for Complex function

$$f(x) = \sum_{k=-\infty}^{\infty} c_k e^{ikx}$$

$[e^{ikx} = \cos(kx) + i\sin(kx)$ Euler expansion $i = \sqrt{-1}]$

$$f(x) = \sum_{k=-\infty}^{\infty} (\alpha_k + i\beta_k)\,[\cos(kx) + i\sin(kx)]$$

$k=0 = \alpha_0 + i\beta_0$

$f(x) = k=0 + k<0 + k>0$

$$\Rightarrow (\alpha_0 + i\beta_0) + \sum_{k=1}^{\infty} (\alpha_{-k} + \alpha_k)\cos(kx) + (\beta_{-k} - \beta_k)\sin(kx)$$

$$+ i \sum_{k=1}^{\infty} [(\beta_{-k} + \beta_k)\cos kx - (\alpha_{-k} - \alpha_k)\sin(kx)$$

if it is real valu $\alpha_{-k} = \alpha_k$ $\beta_{-k} = -\beta_k$.

then there will be no imaginary.

Q Beginig you said $\langle f, g \rangle = \int_{-\pi}^{\pi} fg$

$\psi$ shi

$$\langle \psi_j, \psi_k \rangle = \int_{-\pi}^{\pi} e^{ijx} e^{-ikx}\, dx$$

$$= \int_{-\pi}^{\pi} e^{i(j-k)x}\, dx$$

Hom